INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

DESIGN SOLUTIONS WITH PRODUCT FUNCTION MATRIX AND ITS REQUESTS

M. Karakašić, Ž. Zadnik, M. Kljajin and J. Duhovnik

Keywords: product development, design process, functional modeling, functional matrix, functionality matrix

1. Introduction

Complexity is one of the problems in conceptual design, which is included in modeling and description of design solution. Two groups of descriptions are important for conceptual design: function description and shape description [Kurtoglu, 2007]. In design process, Hubka and Eder, represent products by means of the technical systems [Hubka, 1988]. As technical system, every product has his function. Function represents a link between demands and shape, by achieving description on abstraction level.

Functional modeling is demanding unambiguous in defining of terminology associated with function names and flow [Hirtz, 2002]. On this way, dictionary named functional basis is generated. This dictionary wants to achieve standardization of terminology by using of functional modeling [Kirschman, 1998]. A function on technical system is possible to describe by chaining of physical lows [Žavbi, 2001]. In order to achieve unambiguous in functional modeling, the rules are defined how to list function, functionality and product [Zadnik, 2009].

The aim of design process is in generating a new product conceptual variants and structure of new technical systems by banding functional models with existing technical systems that solve them [Chakrabarti 2004]. Functional requirement and wishes make basement of function and shape interaction. They are determined descriptive and graphics. Functions make descriptive requirements. Shape models or known technical systems make graphics requirements. We are calling them functionalities. Inside conceptual phase, very often matrix methods like morphological matrix [Huang, 1999] are used.

The model of the first structural shape of the product function matrix and its requests model are shown in this paper. Mathematical description of model is described in papers [Zadnik, 2009, Karakašić 2009]. Matrices are making matrix structure by connecting between themselves with binding functions. The functions are described by parameters. Bandage between matrixes is achieved by set of winning parameters. The first structural shape of the product function matrix and its requests model is implemented in developed computer web application. By using computer application, two matrixes are represented. The names of these matrixes are "*Blower*" and "*Diffuser*". Functions and functionalities are bandaged in matrixes. In this way, they make function and shape structure of product named "*Suction unit*". Connection of matrix structure between these two matrices based on binding functions is also explained.

2. Product function matrix and its requests model

Product function matrix and its requests model is developed by expanding model of function and functionality matrix, described in [Duhovnik, 2005]. The product function matrix and its requests

model is developed as a tool to aid the designer in the conceptual design phase to generate new variants of a product on the basis of previously made products. When functions are defined, the matrix correlates these functions on the one side and functionalities on the other side. Functionality is represented by technical systems [Zadnik, 2009]. The product functional structure forms the input into the product function matrix and its requests. Thus the products at different levels must first be connected into a system. By system designing, functions and functional structure is defined. This procedure is detail described in [Zadnik, 2009, Karakašić, 2009].
The product function matrix and its requests model have two structural forms. In this paper is presented the first structural form of product function matrix and its requests. This structural form contains functions and technical systems that solve them. The form is placed on the last level of the listed system. The other, higher-level structural form refers to all other levels that are above the lowest level of the indexed system.

2.1 First structural form of product function matrix and its requests

The first structural form of product function matrix and its requests is illustrated in (Figure 1). Within the product function matrix and its requests the functions are classified by types of functions [Zadnik 2009, Karakašić, 2009].
Building elements represent the technical systems, which form design models. Functionalities are represented through building elements that solve the defined functions.
The column *description* contains the names of functions. For the sake of model simplicity the names are given by common marks.
Each building element can have only one main function. A building element can have one or more supplementary and auxiliary functions. A building element may have no supplementary and auxiliary function. A building element cannot be without at least one binding function in its structure.
Owing to its being unambiguous each function is described by parameters. Depending on the function's complexity, the function can be described by varying number of parameters.
After all the parameters that unambiguously determine the functions have been listed, winning parameters should be chosen. Winning parameters are determined for each function separately, and they represent those parameters that have the strongest impact on a particular function.
Connections between functions and building elements within the product function matrix and its requests are illustrated by the correlation elements in the matrix fields. The correlation elements are of two types interconnected in two ways:

-  connection within the matrix,
-  connection towards the matrices on the same level and the matrices on other levels.

Correlation within the matrix is performed between the main, supplementary, auxiliary and binding functions and the building elements that solve the given functions. When correlating main function and building element that solves it, the set of the main function winning parameters listed in the column *winning parameters* is to be equal to the set of all winning parameters for this type of function of this building element. If this condition is not satisfied, connection between the main function and the building element cannot be realized.
The product function matrix and its requests are composed of its sub-matrices. The sub-matrices are positioned in the direction of the product function matrix and its requests main diagonal (Figure 1). Bindings form the main matrix diagonal.
The product function matrix and its requests is square. It cannot be said that the matrix is completely diagonal due to the fields within which are found the correlation elements outside of the main diagonal. Over these correlations is accomplished connection between building elements inside the product function matrix and its requests.

3. Practical use on real, concrete products

Usability, applicability, functionality, reliability and price are the main purposes of each product. The more the product is useful, applicable, functional, reliable and affordable, the more it can be marketed.

On the other hand, of course all of mentioned things have their price; the price of quality design. Behind each well-defined product, stands well-considered construction and design process. If we want to make a good product, we have to consecrate on it and exactly specify its requirements, features, functionality, parameters and working principles. Up to now we have in our case in detail identified the key most important things that define the theoretical model for a new product function matrix and its requirements. If there is to confirm the adequacy of mentioned, we must prove it on real, rather concrete products cases.

BUILDING BLOCK	FUNCTION	DESCRIPTION	PARAMETERS	WINNING PARAMETERS	FUNCTIONALITY											
					BB1				BB2				BBj			
					M	S	A	B	M	S	A	B	M	S	A	B
					$WP_{BB1\,M}$	$WP_{BB1\,S}$	$WP_{BB1\,A}$	$WP_{BB1\,B}$	$WP_{BB2\,M}$	$WP_{BB2\,S}$	$WP_{BB2\,A}$	$WP_{BB2\,B}$	$WP_{BBj\,M}$	$WP_{BBj\,S}$	$WP_{BBj\,A}$	$WP_{BBj\,B}$
BB1	M	M1	$PM_{BB1\,M1}$	$WP_{BB1\,M1}$	+											
	S	S1	$PS_{BB1\,S1}$	$WP_{BB1\,S1}$		+										
		S2	$PS_{BB1\,S2}$	$WP_{BB1\,S2}$		+										
		Sk	$PS_{BB1\,Sk}$	$WP_{BB1\,Sk}$		+										
	A	A1	$PA_{BB1\,A1}$	$WP_{BB1\,A1}$			+									
		A2	$PA_{BB1\,A2}$	$WP_{BB1\,A2}$			+									
		Ak	$PA_{BB1\,Ak}$	$WP_{BB1\,Ak}$			+									
	B	B1	$PB_{BB1\,B1}$	$WP_{BB1\,B1}$				+				+				
		B2	$PB_{BB1\,B2}$	$WP_{BB1\,B2}$				■								+
		Bk	$PB_{BB1\,Bk}$	$WP_{BB1\,Bk}$				+								
BB2	M	M1	$PM_{BB2\,M1}$	$WP_{BB2\,M1}$					+							
	S	S1	$PS_{BB2\,S1}$	$WP_{BB2\,S1}$						+						
		S2	$PS_{BB2\,S2}$	$WP_{BB2\,S2}$						+						
		Sk	$PS_{BB2\,Sk}$	$WP_{BB2\,Sk}$						+						
	A	A1	$PA_{BB2\,A1}$	$WP_{BB2\,A1}$							+					
		A2	$PA_{BB2\,A2}$	$WP_{BB2\,A2}$							+					
		Ak	$PA_{BB2\,Ak}$	$WP_{BB2\,Ak}$							+					
	B	B1	$PB_{BB2\,B1}$	$WP_{BB2\,B1}$								+				
		B2	$PB_{BB2\,B2}$	$WP_{BB2\,B2}$				+				+				
		Bk	$PB_{BB2\,Bk}$	$WP_{BB2\,Bk}$								■				
BBj	M	M1	$PM_{BBj\,M1}$	$WP_{BBj\,M1}$									+			
	S	S1	$PS_{BBj\,S1}$	$WP_{BBj\,S1}$										+		
		S2	$PS_{BBj\,S2}$	$WP_{BBj\,S2}$										+		
		Sk	$PS_{BBj\,Sk}$	$WP_{BBj\,Sk}$										+		
	A	A1	$PA_{BBj\,A1}$	$WP_{BBj\,A1}$											+	
		A2	$PA_{BBj\,A2}$	$WP_{BBj\,A2}$											+	
		Ak	$PA_{BBj\,Ak}$	$WP_{BBj\,Ak}$											+	
	B	B1	$PB_{BBj\,B1}$	$WP_{BBj\,B1}$				+								■
		B2	$PB_{BBj\,B2}$	$WP_{BBj\,B2}$												+
		Bk	$PB_{BBk\,Bi}$	$WP_{BBj\,Bk}$												■

Figure 1. First structural form of product function matrix and its requests

Based on the developed computer application [Karakašić, 2009], we will continue with briefly presentation of two matrices titled "*Blower*" (Figure 2) and "*Diffuser*" (Figure 3). Both matrices arise and are based on the analysis of real product called "*Suction unit*". In the beginning of the process, we fist generate and fulfill input lists of solutions which are based on the available database and computer application algorithm. In input lists of solutions we prepare all necessary solutions, information and data to generate a product function matrix and its requests. The following matrices display inventory and inter-related, inter-bonded functions and functionalities that make up the functional and design structure of the product named "*Suction unit*".

3.1 Binding of matrix "Blower" with matrix "Diffuser" and inverse

Matrix named "*Blower*" is associated with matrix named "*Diffuser*" over one binding function. Matrices are associated or better to say connected with binding function called Fluid flow transfer. In the matrix "*Blower*" this function is resolved by the building block "*Blade*" and in the matrix "*Diffuser*" by the building block "*Diffuser blades*".

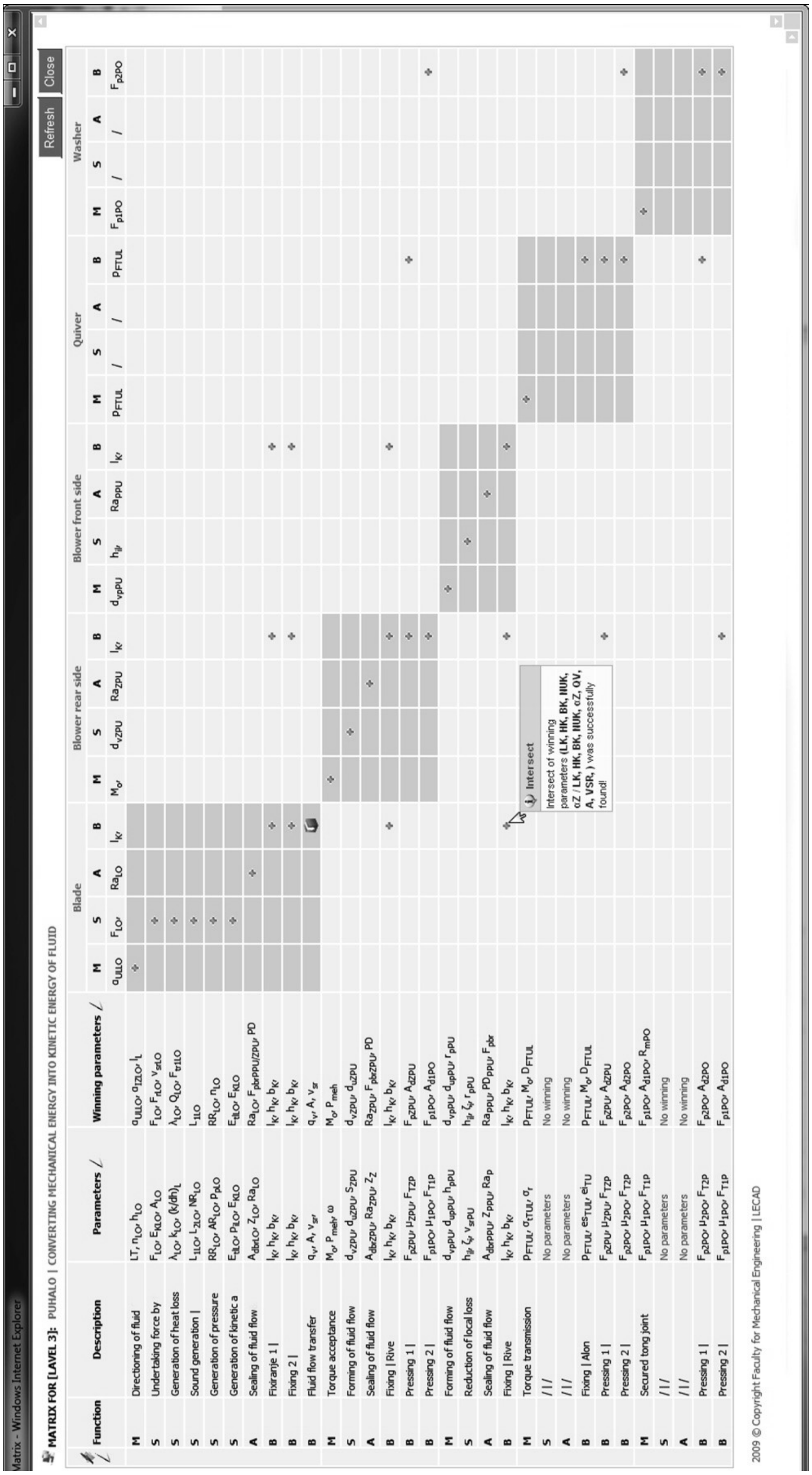


Figure 2. First structural form of product function matrix and its requests of function "*Transfer of mechanical energy into kinetic fluid energy*" on "*Blower*"

For the upper function within the matrix "*Blower*", we can open a new window of bindings by clicking the binding link provided. Inside the window a link is displayed and defined on the basis of linkage to other matrices; so the matrices at the same level as the other matrices at other levels. In our case, binding link is displayed, which leads to the matrix “*Diffuser*” and “*Diffuser blade*”. Window is shown in Figure 4a. By activating the link for connection to other matrices at the same level and other matrices on other levels for the function “*Fluid flow transfer*” within the matrix “*Diffuser*”, the window will open with a link that leads to the matrix “*Blower*” and building block “*Blade*”. Window is shown in Figure 4b.

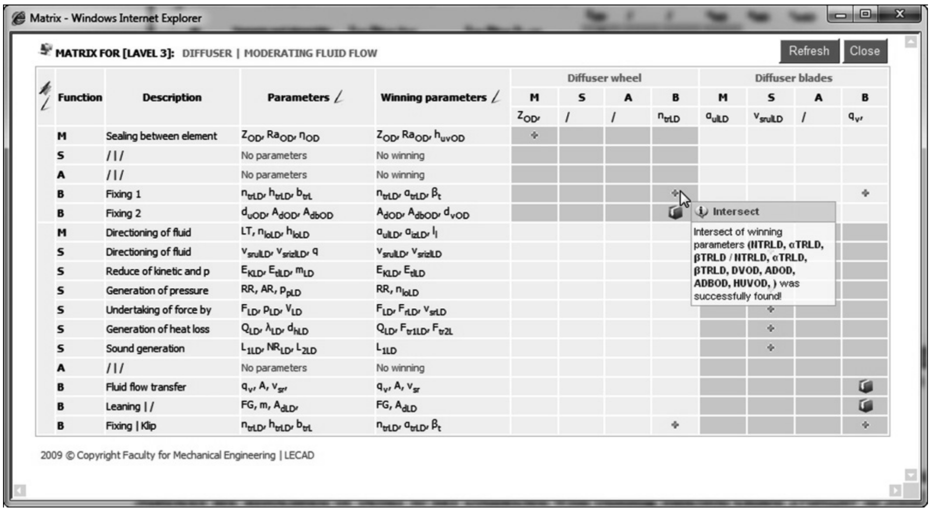
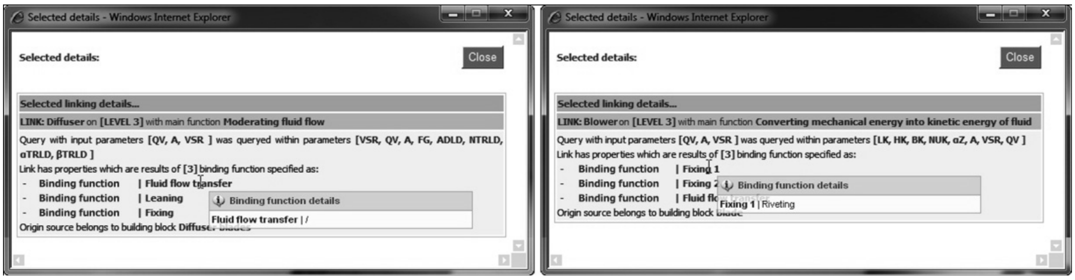
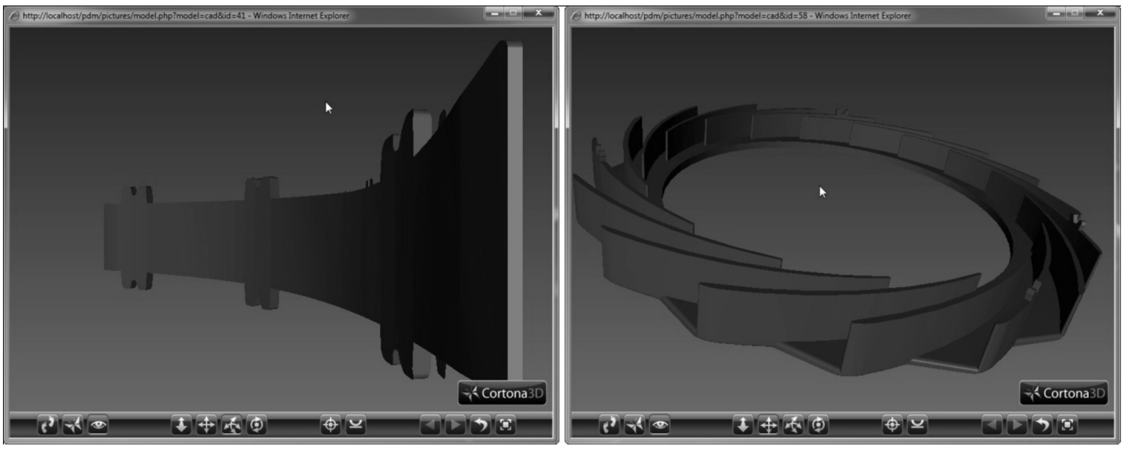


Figure 3. First structural form of product function matrix and its requests of function “*Calming of fluid flow*” on “*Diffuser”*



a **b**

Figure 4. a-Binding link for matrix “*Blower*” with matrix “*Diffuser*” with function “*Fluid flow transfer”*; b-Binding link for matrix “*Diffuser*” with matrix “*Blower*” with function “*Fluid flow transfer*”



a **b**

Figure 5. a-Shape model of "*Blade*"; b- Shape model of "*Diffuser blades*"

In developed computer Web application every building block is described by functions and stored in central database. Beside description containing functions, it is possible to determine description by shape. This description is generated in Computer Aided Design (CAD) systems. In separate window of developed Web application building blocks for binding function "*Fluid flow transfer*" are displayed (Figure 5a - 5b).

4. Conclusion

The first structural shape of the product function matrix and its requests model is developed tool that enables designer to generate product matrix structure, by bandaging matrix model with binding functions. In matrix structure, product functions are listed with functionalities that solve them. Functions and functionalities are bandaged with links by set of winning parameters. Inside the matrix appears the property of sub matrix. In this way, constructor can prove that he or she is on the right track. If the property of sub-matrix doesn't show up, design process is going in wrong way. Consequently the system of functions is wrong and functionalities are redundant or better to say not applicable for use. In this way, the constructor can re-examine his or her idea and compare it with previous construction solutions.

Developed matrix model in comparison with morphological matrix provides exactly mathematically defined design process by set of exact rules and not only by designer intuition like morphological matrix.

Acknowledgement

The work presented in this paper is financially supported by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia and the Ministry of Science, Education and Sports of the Republic of Croatia through a bilateral project.

References

Chakrabarti, A., "A New Approach to Structure Sharing", Journal of Computing and Information Science in Engineering, Vol.4, No.11, 2004, pp. 11-19.

Duhovnik, J., Tavčar, J., "Product Design Test using the Matrix of Functions and Functionality", Proceedings of AEDS 2005 Workshop, Pilsen-Czech Republic, 2005.

Hirtz, J., Stone, R.B., McAdams, D.A., Szykman, S., Wood, K.L., "A Functional Basis for Engineering Design: Reconciling and Evolving Previous Efforts", NIST Technical Note 1447, Department of Commerce United States of America, National Institute of Standards and Technology, 2002.

Huang, g.o., Mak, K.L., "Web-based morphological charts for concept design in collaborative product development", Journal of Intelligent Manufacturing, Vol.10, No.3/4, 1999, pp. 267-278.

Hubka, V., Eder, W.E., "Theory of Technical Systems", Springer-Verlag, Berlin, 1988.

Karakašić, M., Zadnik, Ž., Kljajin, M., Duhovnik, J., "Product Function Matrix and its Request Model", Strojarstvo, Vol. 51, No. 4, 2009, pp. 293-301.

Kirschman, C.F., Fadel, G.M., "Classifying Functions for Mechanical Design", Journal of Mechanical Design, Vol.120, No.3, 1998, pp. 475-482.

Kurtoglu, T., "A Computational Approach to Innovative Conceptual Design", PhD thesis, The University of Texas at Austin, Austin, 2007.

Zadnik, Ž., Karakašić, M., Kljajin, M., Duhovnik, J., "Functional and Functionality in the Conceptual Design process", Strojniški vestnik, Vol.55, No. 7-8, 2009, pp. 455-471.

Žavbi, R., Duhovnik, J., "Conceptual design chains with basic schematics based on an algorithm of conceptual design", Journal of Engineering Design, Vol.12, No.2, 2001, pp. 131-145.

Mirko Karakašić dipl. ing. stoj.
Assitant professor
Department for Mechanical Design
Mechanical Engineering Faculty Slavonski Brod
Trg Ivane Brlić-Mažuranić 2, 35000 Slavonski Brod, Croatia
Email: mirko.karakasic@sfsb.hr
URL: http://www.sfsb.hr